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Microstructure and Mechanical Properties of High Power CO_2 Laser Welded Joint of Mg-Rare Earth Alloy NZ30K

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Abstract

The weldability of a 9.5 mm thick Mg-Rare earth alloy NZ30K using 15 kW high power CO_2 laser was studied. The microstructure and mechanical properties of the typical welded joints had been analyzed and tested. When using the right laser welding parameters, good weld forming can be obtained. The microstructure of the fusion zone is small equiaxed grains. There is no softening zone to be observed according to the micro-hardness distribution across the welded joints. The results show that the thick Mg-Rare earth alloy NZ30K plate can be welded by the high power CO_2 laser with good weld quality.

Keywords: Laser joining; Magnesium-rare earth alloy; Microstructure; Mechanical property

1. Introduction

In recent years magnesium alloy is strongly developed, which is well known as the 21st century green project material because of low pollution to the environment, energy-saving and satisfying the requirement of sustainable development. So the magnesium alloy is used more and more in automotive, electronics, aerospace and other fields. In order to improve the strength properties of magnesium alloy at high temperatures, a new magnesium alloy NZ30K that is alloyed with the rare earth element neodymium (Nd) has been developed [1]. It can be used for such as hub of car wheels, bracket of car engines and door parts. However, the inherent characteristic of magnesium alloy makes easier to produce weld defects and deterioration of properties in heat affected zone in welding. It is difficult to obtain high-quality welding joints by conventional welding methods [2]. High-power laser can reduce the magnesium alloy welding defects because of its unique advantages. There is a sum of researches on the laser welding of magnesium alloys in sheet form [3-5], and M. Marya et al. [6] studied the laser welding process of 8 mm thick AM50 and AZ91 magnesium alloy materials. Generally the welding research on thick magnesium alloy plate and Mg-Rare earth alloy is quite less. In this paper, the investigations focused on the microstructure and mechanical

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properties of the welded joints of thick Mg-Rare earth alloy using high power CO_2 laser.

2. Experimental material and methods

The experimental material is the hot-rolled Mg alloy NZ30K without sequent heat treatment, which is alloyed by the rare earth element Nd and the elements Zinc (Zn) and Zirconium (Zr). Its chemical composition is listed in Table 1. The tensile strength and elongation of the alloy NZ30K is 195 MPa and 5% respectively.

Table 1. Chemical compositions of the NZ30K (wt,%)

Compositions	Nd	Zn	Zr	Mg
Content	2.5~3.5	0.2~0.4	0.3~0.5	balance

The microstructure of the base metal (BM) consists of α phase as base and β phase ($Mg_{12}Nd$) distributed along the grain boundary, shown in Fig. 1. A hot-rolled strip organization without the obvious grain boundary could be observed.

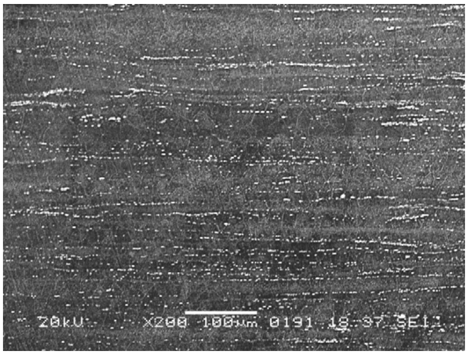

Fig. 1. Microstructure of the base metal

The size of test specimens is 150mm*50mm*9.5mm. A CO_2 Laser source (TRUMPF TLF15000T) with a maximum output power of 15 kW and the laser beam focus diameter of 0.8mm was used. The pure helium was used as side-blown gas and the back side of specimens was protected by pure Argon.

Prior to welding, the surface oxide film of the specimens was removed using a steel brush and then cleaned by acetone. The welding was carried out in flat position with two optimized different sets of parameters. The welding parameters are listed in table 2. The microstructure of the typical welds was observed by JSM-6460 Scanning Electron Microscope. After welding, the hardness of welded joints was tested using a digital Vickers hardness tester under the load of 500 mg, and the tensile properties were tested by a Zwick Z020 E-stretching machine.

Table 2. Typical welding parameters

Sample	Laser power P (kW)	Welding speed *v* (m/min)	Focal position Fp (mm)	He gas flow Q1 (L/min)	Ar gas flow Q2 (L/min)
A	8	1.2	-2	25	20
B	7	1.8	-2	25	20

3. Results and discussion

3.1. Cross section of weld bead

The weld cross section of the two welding samples is shown in Fig. 2. They are characterized with full penetration and free of macroscopic defects in the fusion zone. As shown in Fig. 2, the width of the sample A is evidently wider than that of the sample B. Because, in comparison with sample B, the laser power of sample A is higher and the welding speed is slower, the heat input for sample A is therefore much higher than sample B. The high heat input makes the weld width wider.

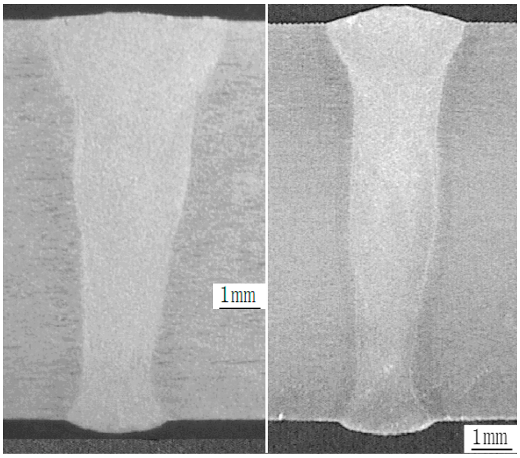

Fig. 2. (a) Cross-section of the weld bead of sample A; (b) Cross-section of the weld bead of sample B

3.2. Microstructure of welded joint

The microstructure of the welded joint is shown in Fig. 3. As seen from Fig. 3(a), the right area is the fusion zone (FZ) that consists of numerous small equiaxed grains. The middle area is the heat affected zone (HAZ) consisting of big grains with evident grain boundary. The left area is the base metal with hot-rolled strip organization. The average diameter of the grains in HAZ of sample A is 28.6 μm, but it is 21.1 μm in sample B. With the increase of heat input, not only the width of HAZ but also the grain size becomes wide significantly.

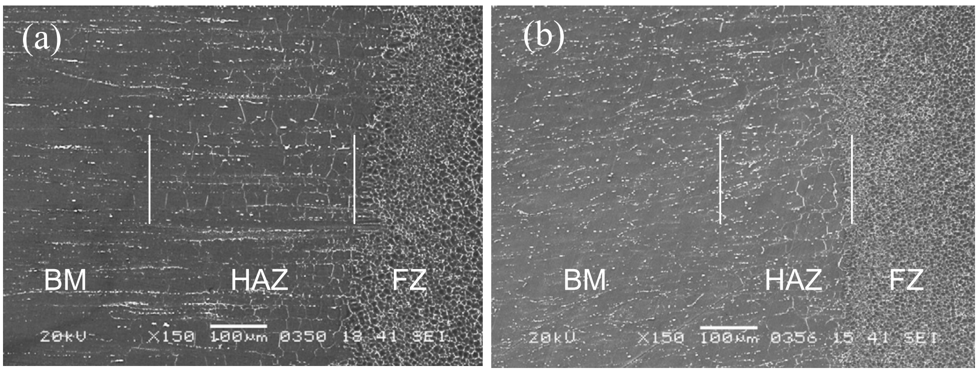

Fig. 3. (a) Microstructure of the welded joint of sample A; (b) Microstructure of the welded joint of sample B

The microstructure of the fusion zone of both samples under even higher amplification is shown in Fig. 4. As NZ30K alloy contains Zr element that acts as the grain refiner during the solidification, the chances of non-spontaneous nucleation would be increased, which could prompts the formation of equiaxed grains in the fusion zone. In Fig.4 it can be seen that the grain size in FZ of sample A is significantly larger than that of sample B. The average diameter of the grains in FZ of sample A is 11.8 μm, and it is 6.5 μm of sample B. Because of high heat input the crystallization rate in FZ of sample A is low and grains have more time to grow, which results in coarse grains.

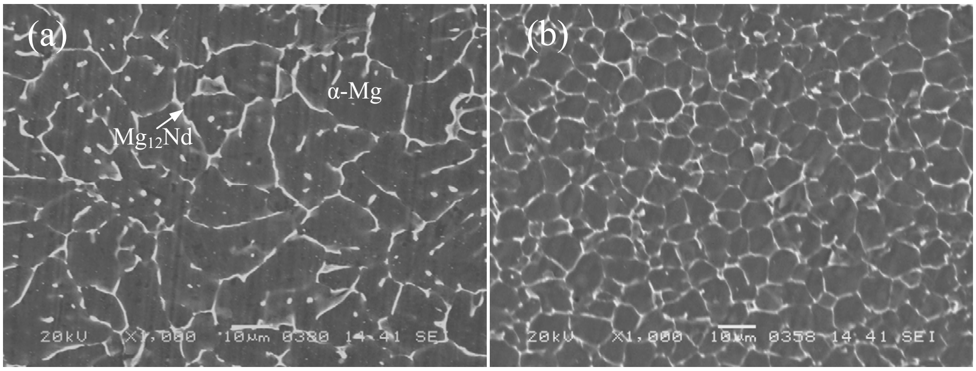

Fig. 4. (a) Microstructure of the fusion zone of sample A; (b) Microstructure of the fusion zone of sample B

3.3. Micro-hardness of the welded joint

The Vickers micro-hardness of the welded joint is shown in Fig. 5 and Fig. 6. It can be seen that the micro-hardness of two welded joints has little difference. As the grains in FZ and HAZ of sample B are smaller, the micro-hardness of sample B is lightly higher than sample A. The micro-hardness distribution shows that the hardness across the welded joint A is almost the same. There is no obvious softening zone in welded joint A, but a lightly reduction of hardness in HAZ of sample A. The micro-hardness along the weld depth has almost no change.

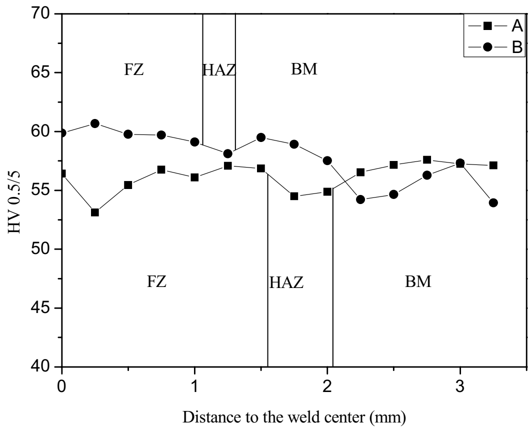

Fig. 5. Micro-hardness distribution across the welded joints

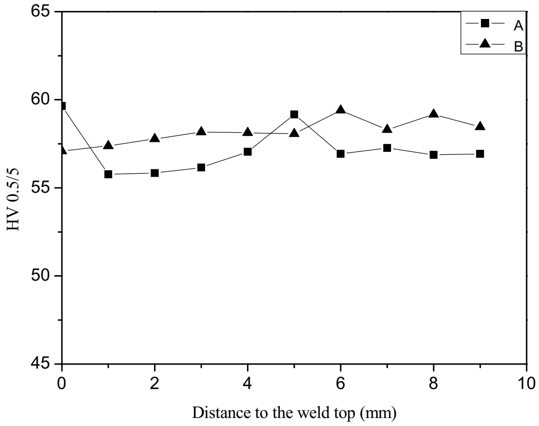

Fig. 6. Micro-hardness of the weld bead in depth direction

3.4. Tensile strength of the welded joint

The stress-strain curves of specimens are shown in Fig.7 and the results of the tensile strength are listed in Table 3. Tensile specimens were broken in the base metal region, which indicates that the tensile strength of welded joints is higher than that of base material. This is due to the grain refinement in fusion zone and HAZ. It can be seen from the table 3 that the elongation of sample B is higher than sample A and the base metal, which is a result of finer grain in FZ and HAZ of sample B. The results shows that the high power laser welded joints of Mg-Rare earth alloy NZ30K have good mechanical properties.

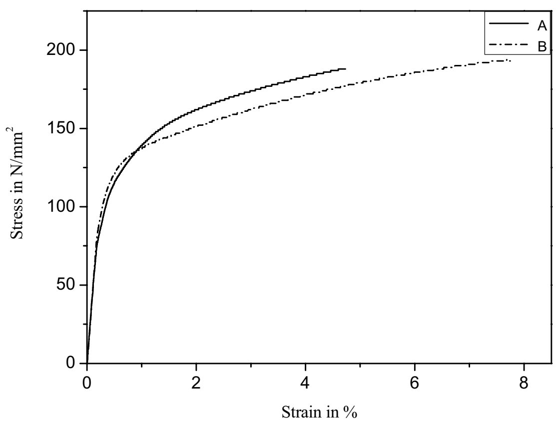

Fig. 7. Stress-strain curves of the welded joints of sample A and B

Table 3. Tensile strength of the sample A and B

Sample	Rp 0.2 N/mm2	Rm N/mm2	Agt %
A	112.25	188.18	4.72
B	117.18	193.55	7.69

4. Conclusions

(1) Using the high power CO2 laser the 9.5mm thick Mg-Rare earth alloy NZ30K can be welded with good joint appearance under the applied welding parameters, where joint is full penetrated and free of macro defects in the fusion zone.

(2) There are numerous small equiaxed grains in the fusion zone. With the increase in the amount of welding heat input, the HAZ becomes wider and the grain size in the HAZ is increased.

(3) The high power welded joints of thick Mg-Rare earth alloy NZ30K have good mechanical properties. There is no obvious softening zone observed in welded joints. The tensile strength of welded joints is higher than that of base material. Low welding heat input leads to a high elongation of joint.

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